

Surface ozone in the Kiev city, factors and conditions of its formation, sources and sinks.

A contribution to subproject SATURN

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The main factors and conditions determining an enhanced background of the ozone concentration in the lower troposphere above the Kiev city are classified and analyzed. Accounting for differences of emission characteristics three groups of sources of ozone forming pollutants (nitric oxides, carbon monoxide, sulphur dioxide, hydrocarbons) - low, elevated and high are distinguished. Traffic emissions, being main fraction of low sources, are followed by the most intensive air pollution in central and western (along the ring road) parts of city, and also in separate parts of Left-bank zone. Taken the city as a whole, we can estimate the contribution of a vehicle emissions to total amount of ozone precursors as 35-40 % . The elevated sources (their numbers are more than 200), to which one concerns of a various type heating facilities, waste recycling factories (combine "Energia"), the altitude of ejection of which does not exceed 30-35 m, are dispersed on terrain of city (800 ê²) rather evenly. Not looking that their aggregate contribution does not exceed 10-15 %, the effect of elevated sources on a level of pollution of separate (local) sites at a particular weather conditions appears prevailing. The considerable fraction of pollution for a ground layer and main part of pollution for all depth of a boundary layer of atmosphere and free atmosphere (within the limits of the lower troposphere) are contributed by thermal power stations , altitude of tubes for which is 120-270 m. Most powerful of them are located in a left-bank part of city and effective at east transfer of air mass, in particular at elevated inversions of air temperature.

For an estimation of ground pollutant concentrations from high sources the numerical calculations with the help of composite diffusive model are carried out, in which the intensity of dissipation of pollutants on a horizontal was allowed statistically, and on a vertical - with the help of a factor of vertical turbulent diffusion. The concentration was calculated as a single, mean for the 20-minute period. Annual average pollutant concentrations were calculated as mean arithmetic value of single or mean diurnal concentrations calculated accounting for emissive characteristics (taking as constants) and meteorological ones (observed in 2000). The maps of annual average ground concentrations of ozone precursors emitted from high sources are constructed with a step of 0.01 degree. Some climatic maxima of surface concentrations are allotted, mutual arrangement and values of intensity for them are determined by parameters of stacks (height and diameter of stacks, speed and temperature of ejected flue gases, power of ejection) and meteorological parameters. Because of taking into account only the high sources the calculated values can be accepted as the lowest limits of possible concentrations. A justification of calculated concentrations outcomes from joint consideration of them and data of state monitoring stations for air pollution of the Kiev city. As it was supposed, the computed (Figure 1.) and observed zones of the enhanced concentrations NO₂ are coincide in location, but measured absolute annual average values exceed (sometimes essentially) or are comparable with calculated ones.

Dynamics of formation of fields of measured ground level concentrations of ozone precursors was analyzed depending on predominance of synoptic situation and meteorological characteristics. It is revealed, that basic synoptic processes contributing to formation of high

levels of ozone precursors are: stable ("blocking") anticyclones, shift-resist ridges, low-gradient fields of enhanced pressure and pressure col. Just at these synoptic processes the atmosphere is most steady stratified, that is confirmed by the computed values of a category of its stability (on Pasquill-Ulig). Especially favourable situations for photochemical processes due to low and elevated sources were marked per clear days with a lower turbulence (at intensive ground and elevated inversions of air temperature and pollutants transport in a direction of point of measurements. At conversion from steady processes in atmosphere to unstable and strengthening of wind velocity the level of ground concentrations is influenced by high sources, the injection from which during a convective ascending - down gusts are transported to a surface of ground. The joint analysis of monitoring data of ozone precursors, characteristics of pollution sources, calculated and measured fields of ground level concentrations, data about nitrogen dioxides NO_x contents (as a basic regulator of photochemical process of ozone formation) allows us to suspect about almost year-roundy enhanced ozone levels above Kiev, which increase in the summer, in particular at favourable for smog formation synoptic situations, and reduce in the winter, when turbulent transport and intensity of ultraviolet radiation decay. The results of measurements of NO_2 concentration show that the Kiev city domain involves both NO_2 controlled areas of ozone pollution and VOC controlled ones.

With the purpose of studying features of formation of surface ozone within the limits of Kiev, detection of the factors and conditions, which contribute in its accumulation and sink, the estimation of the sanitary-hygienic significance of forming ozone levels are held as contact measurements in one point and remote measurements of O_3 concentration on a path. The sites of measurements were located in a southern part of city at Botanical Garden NANU (contact) and in a wood zone - GAO NANU (remote) at the distant from several hundreds meters up to 2 kilometers from motor-ways and 4 - 8 kms from high stacks of large-scale thermal power stations. The measurements were conducted with the help of the ultraviolet ozonometer TEM49. The data obtained were analysed together with emission rates of ozone precursors, meteorological and aerological parameters. Weight hourly, mean daily, monthly mean, seasonal and as a whole for a calendar year values of concentrations of ground ozone. 13 types of diurnal variation \hat{I}_3 are detected and reviewed their character features: predominance one and bimodal O_3 distributions, formation of rather high levels \hat{I}_3 in night time, drop of a daily amplitude \hat{I}_3 in the rainy season and in winter. For an explanation of high levels of surface ozone (almost constant enhanced concentrations above maximum limits), features of their dynamics the information about a nature of photochemical processes in urban atmosphere, and also role of separate species (in particular oxidants) are generalised. Apparently the bimodal daily O_3 variation is a result of impact of second (afternoon) maximum of traffic emissions; the heightened O_3 surface concentrations in the summer night time arise due to sinking from upper layer ozone generated in daylight, and the wet deposition and decomposing ozone in a rainy weather promote low O_3 levels. In a seasonal O_3 variations the greater effect is due to large-scale factors (natural - duration and intensity of solar radiation, anthropogenic - duration of a heating season etc.).

On the basis of the combined analysis of observed series of ground O_3 concentrations, meteorological and emissivity parameters the principles of possible prediction of high levels of troposphere ozone are substantiated depending on ozone precursor air pollutions, types of synoptic situations, current meteorological characteristics and possible intensity of photochemical processes. One-point ozone measurements in the city with very rugged terrain and dispersed high-power sources of ozone forming species do not yield a full picture about O_3 levels in Kiev. In this connection the method is justified and the technique is developed for remote measurements of ground ozone concentrations with the help of Fourier - spectrometer

having of essential advantage in comparison with contact measurements in one point. The regular remote observations are planned in nearest time. With the purpose of an estimation of a climatic role of formation of ozone within the limits of influencing large industrial city (Kiev) the possibility of using of three-dimensional mathematical model based on the K-theory of a turbulence, simultaneously taking into account transport and dissipation of ozone forming species, emission characteristics, photochemical reactions, dry and wet deposition of pollutants for calculation of concentrations of surface ozone at various locations and altitudes is analyzed. The chemical modelling of ozone episodes with UAM-5 model are started.

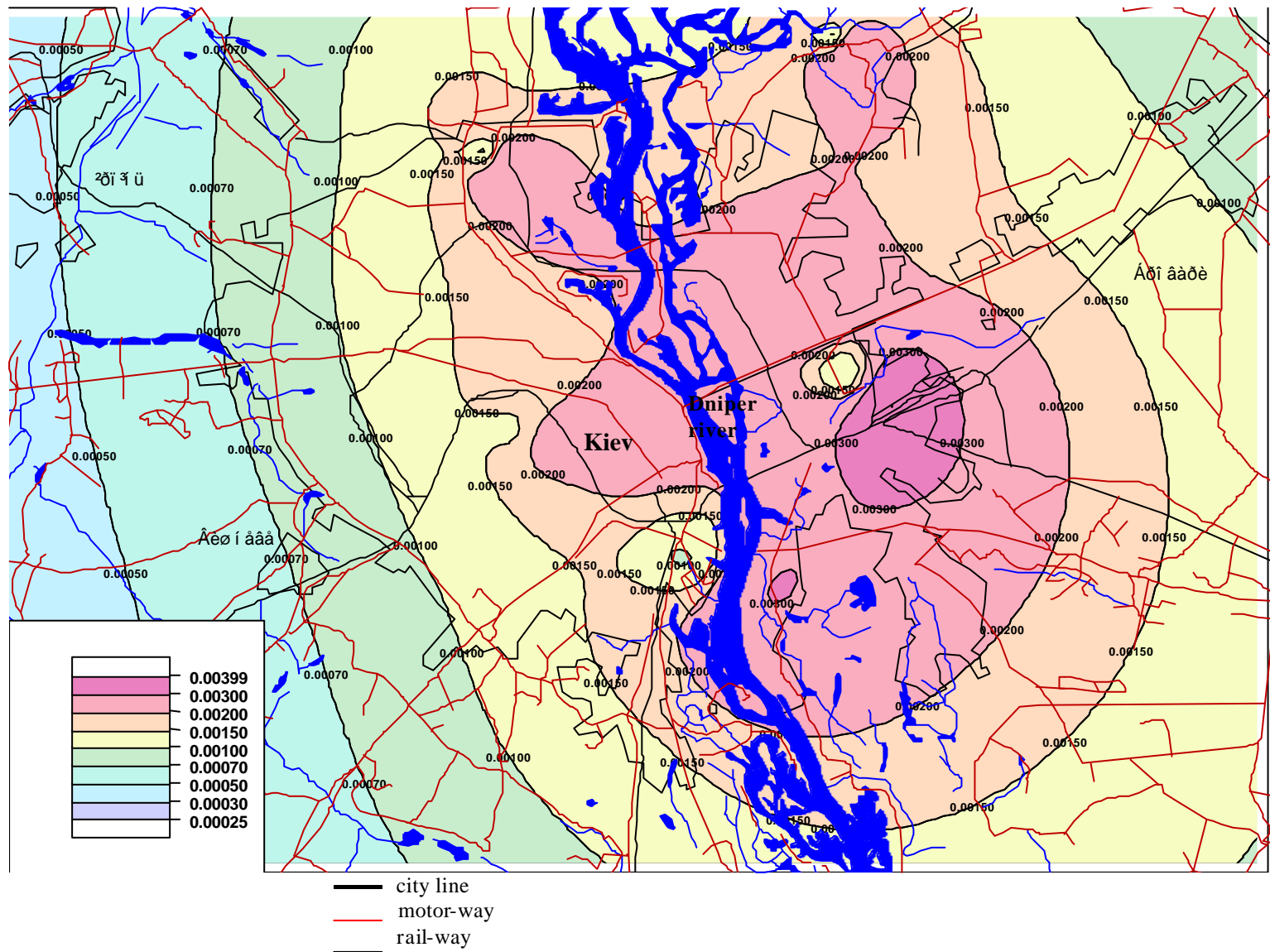


Figure1. Annual average surface NO₂ concentrations (mg/m³).